Development of Social Virtual Reality (SVR) as Collaborative Learning Media to Support *Merdeka Belajar*

Hestiasari Rante, Muhammad Agus Zainuddin, Cahya Miranto*, Felix Pasila, William Irawan, and Evianita Dewi Fajrianti

***Abstract*—Merdeka Belajar (the freedom to learn) in Indonesia emerged indirectly with the COVID-19 pandemic. Merdeka Belajar is a form of learning that aims to create an innovative, non-restrictive learning culture. With this idea, the development of online education is growing rapidly from online meetings to a virtual format and the development of online resources, rapidly available and broadly accessible. Social virtual reality (SVR) refers to popular 3D virtual spaces in which multiple people can engage with one another. This research aims to develop an SVR application as learning media by implementing Meta Avatar SDK with voice chat and lip sync features to mimic facial expressions. Based on the performance testing results, the application can render at an average of 76 frames per second. Based on the results of trials to 14 respondent, we measure satisfaction and interest level using the PIECES (performance, information and data, economics, control and security, efficiency, and service) Framework. The average value of interest is 4.19 and the average value of satisfaction is 4.13. This proves that the respondents are interested and satisfied with the SVR application as a learning medium.**

***Index Terms*—Collaborative, education, Meta Avatar, social virtual reality, virtual learning**

I. Introduction

Education has been adapted to a variety of digital platforms over the years. Since the case of the pandemic, online learning using personal computers (PCs) and mobile devices has become extremely common. Modern learning platforms offer content access through a variety of client applications (desktop, mobile, and web-based), sharing, monitoring, and personalized experiences [1]. In addition, new platforms for virtual worlds (VWs) or the metaverse are emerging as options for online learning. VW combines multiple technologies, including voice, text, camera, audio, video, and digital avatars, onto a single platform.

Collaborative virtual environments (CVEs) are a type of VWs that offers a more robust collaborative environment for networking and social interaction. Examples of uses for CVEs include cooperative games, interactive art, simulations, distance learning [2], virtual tours of buildings, cultural heritage sites [3], and social entertainment. For students who require assistance with their learning process, CVEs can provide a variety of features [4].

Merdeka Belajar (the freedom to learn) in Indonesia emerged indirectly as a result of the COVID-19 pandemic. Merdeka Belajar is a form of learning that aims to create an innovative, non-restrictive learning culture and is in line with the needs of students [5]. The COVID-19 pandemic sparked the idea of Merdeka Belajar in the 4.0 industrial age, when students are expected to study independently using online resources. Numerous learning management systems (LMS) have been developed by software developers, businesses, and universities to make online education more accessible. Conventional or in-person learning has been replaced by virtual learning as a result of the COVID-19 epidemic [6].

Online social spaces appear to be leading to increasingly nuanced forms and experiences of collaboration, as well as unique approaches to support computer-mediated collaboration, as they continue to advance towards more immersive and high-fidelity experiences. Social virtual reality (SVR) refers to popular 3D virtual spaces where multiple individuals can interact using virtual reality (VR) Head-Mounted Displays (HMDs) [7, 8]. Instead of relying solely on looking at a computer screen, SVR fundamentally transforms how people connect, communicate, and socialize through immersive 360-degree environment, voice communication, and full-body tracking avatars. Due to this distinction, SVR is a promising new CVE that enables people to participate in a variety of collaborative activities in a more engaging way [9–11].

Current virtual reality (VR) technology enables intercontinental communication and collaboration in shared virtual environments (SVEs). However, the quality and effectiveness of communication and collaboration in VR are frequently influenced by aspects such as avatar representation, virtual environment rendering, state synchronization, and latency [12]. Mainly, avatars are essential in social VR, and their realism is a major factor in how we experience presence, social interactions, and copresence [13–16].

We plan to use collaborative learning to address a problem in education by integrating VW platforms. In this paper, we aim to develop an SVR application by implementing Meta Avatars SDK with multi-user and voice chat capabilities. First, we review related work regarding collaboration and education in VWs.

II. Related Work

He and Du *et al.* developed CollaboVR [17], a

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reconfigurable VR framework with an animated sketching feature, a collaborative virtual area and multi-user communication in real-time. CollaboVR features four custom layouts to test the experience suitable for virtual discussions using an interactive board. However, the application development uses 1st generation VR hardware which requires a tracking sensor hardware, limiting the user's space and the range of movement for the virtual avatars to just the head and hands. Similarly, Wang *et al.* developed ReliveInVR [18], allowing multiple users to experience a shared virtual reality environment. However, the ReliveInVR prototype utilized low-resolution, one color mannequin-like avatars, which limited the players' gestures and reduced the effectiveness of nonverbal communication cues.

Ahlers and Bumann *et al.* develop Hololingo! [19] An SVR tandem app for real-time immersive distance learning of German as a Foreign Language (GFL). The app includes several scenes specifically designed for language teaching, such as the introduction scene and scenes with game elements like word puzzles and a maze with quizzes or clues for language training. However, the development of Hololingo! relies on the VRChat platform and its SDK. Mei and Li *et al* developed CakeVR [20], an SVR application that allows customers and chefs to collaborate on cake designs in a virtual bakery. Testing of the application on users resulted in a recommendation to add a facial expression feature and controls to move in the virtual area. Friston *et al* developed Ubiq [21], a toolkit for building cross-platform SVR in Unity. Ubiq provides a menu system that enable the creation of both public and private rooms. Users can express themselves through voice chat and head and hand gestures, but there is no feature to control facial expressions.

In this research, we will build a multi-user SVR application using the Meta Avatar SDK, which includes facial expression features (like eyes and mouth animation) using voice recognition and has several custom avatars. XR input development and integration will use Unity and OpenXR so that applications can stand alone without being dependent on other platforms. The app will be able to run on Oculus Quest 2, a 2nd generation VR device that is more affordable and efficient because it does not require a large space or a connection to a PC. Oculus Quest 2 is built with Android, which allows it to operate as a standalone device.

III. Research Method

The research project aims to develop SVR applications as online learning media to support Merdeka Belajar (the freedom to learn).

A. Sample and Procedure

The respondents for this study were university students enrolled in a Basic Programming course for the first year of their Informatic Engineering degree. In the experiment, the 14 student participants had learned about about variables and types, arguments and input-output in Phyton.

The quiz material for the research experiment will be in the the form of basic Python programming, with 20 multiple-choice questions to be used as test material in the quiz feature of the SVR application.

B. Data Analysis

After completing the learning experiment using SVR, the respondent were asked to fill out a questionnaire. The design of the questionnaire will refer to the PIECES Framework method. PIECES Framework is a problem-solving framework used to frame your investigation of the problems, opportunities, and requirements. PIECES Framework has 6 scope analyses: Performance, Information and Data, Economics, Control and Security, Efficiency, and Service [22].

C. SVR Application Feature

Before developing the application, we must design the feature requirements necessary to replicate the learning process in virtual world. In general, the learning process involves interaction between users, for example between fellow students or between students and lecturers, and the use of media to complete assignments, exams, or quizzes in the virtual world.

Based on these needs, we have identified the following main feature points

1) Avatar, to represent oneself in the virtual world
2) Voice chat, as a medium of interaction between users
3) Multiplayer, to allow multiple users to use the SVR application
4) Quiz system, as a learning tool or test

IV. Result

A. SVR Design Architecture and Implementation

Based on the previously identified feature requirements, an SVR application will be developed with architecture as shown in Fig. 1. In the Unity engine, there will be several supporting objects to form a scene, such as 3D models, materials and textures, lighting and rendering settings, UI, quiz system, Meta Avatar SDK and XR Plugin. The Unity client will connect to the server using Photon server.

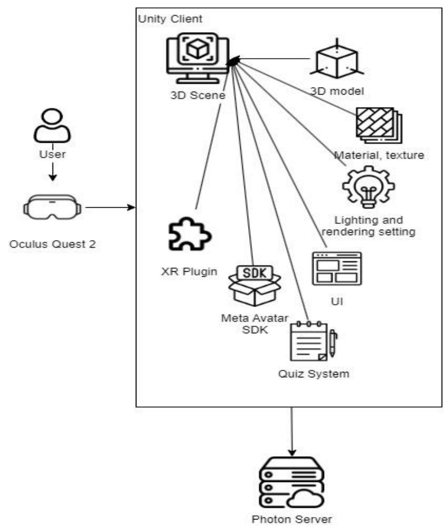

Fig. 1. SVR system architecture.

The XR plugin is a plugin for integrating VR hardware such as Oculus Quest 2 into the Unity game engine. The Meta Avatar SDK is used because the SDK has several sample avatars with simple rigs that can be used and has the feature of moving the avatar's mouth based on the sound of the user's mic input.

Fig. 2 is the use case of the SVR application. There are two types of users in this application: teachers and students. Teacher and student will automatically join a room created by system and can interact with each other by activating voice chat. Teachers can manage quizzes and review quiz results. Students can view and answer quizzes through a UI that will appear in front of their avatar.

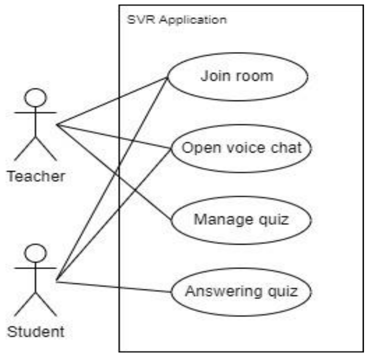

Fig. 2. Use case SVR application.

The developed SVR application includes a question bank with 20 multiple-choice questions on basic programming for users to test the system. Users can take quizzes by viewing questions through the quiz UI and pressing the button to answer questions.

Fig. 3 shows the scenario flow of the built SVR application. First, when the user runs the app using Oculus, the app will authenticate the Meta account based on the Oculus login account. After the account is authenticated, the application will create the lobby host if the lobby host is not found. Furthermore, if a new user joins, they will automatically enter the hosted lobby.

After entering the lobby, the application automatically generates an avatar for the user. Currently, there is no feature for avatar customization, so avatars are generated randomly. After being generated, the user can move around the lobby area and their avatar will follow the user's hand and head movements. Users can interact via voice chat by talking through the mic on the Oculus Quest 2 HMD (Head Mount Display). The mouth on the avatar will move in response to the user's voice input.

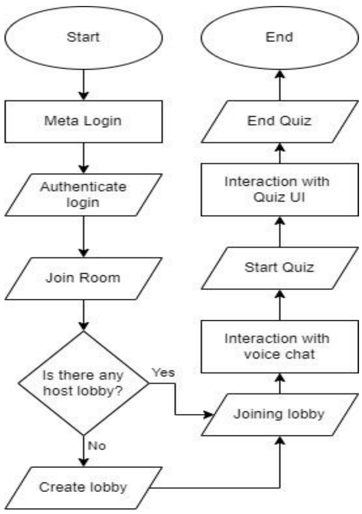

Fig. 3. SVR scenario.

The design starts from designing the lobby scene (Fig. 4). The lobby scene is the entire area for learning activities and consists of several objects, such as ground and tree objects, a lobby area, and other supporting properties. Currently, the system only supports one lobby area, so it does not support parallel learning processes that require multiple areas.

Next is to place the spawn point (red dot in Fig. 5) using an empty game object from Unity. By default, empty game object only have transform data like position, rotation and scale. In this scene, five empty objects will be placed around the table, later programmed as spawn points. The spawn point will serve as the user's initial position when they join the scene. When the user runs the SVR application and joins the room, the system will automatically select one of these five spawn points as the user's initial position. It is used to avoid characters appearing at one coordinate and overlapping the user avatar.

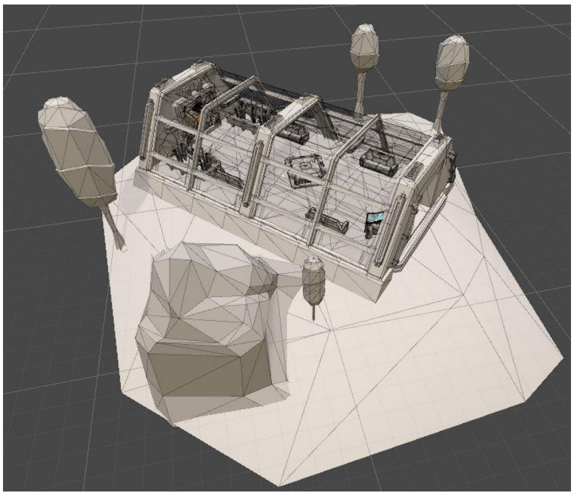

Fig. 4. SVR lobby scene design.

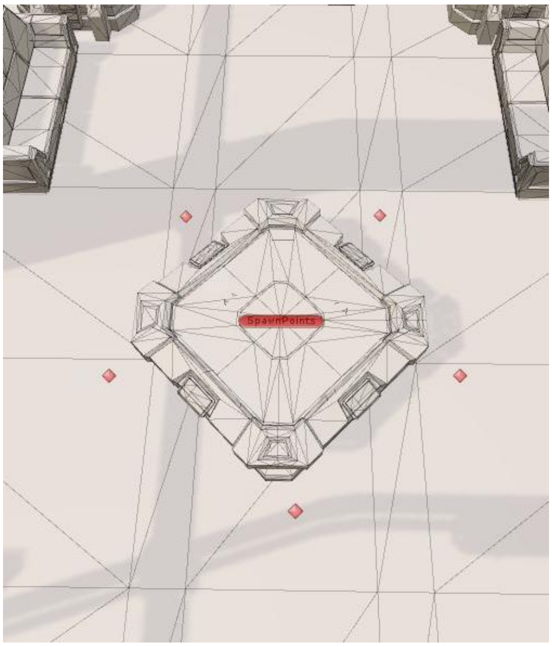

Fig. 5. Generate spawn point.

For the multiplayer part, this development uses Photon Pun 2. Photon Pun 2 provides a cross-platform multiplayer game backend as a service for synchronous and asynchronous games and applications. First ensure connection to Photon server using the command

PhotonNetwork.ConnectUsing- Settings. This command will connect all users to a lobby. Each application has its own AppID that will connect to the same lobby. When the user is connected to a lobby, they have not yet moved to the main scene. Photon is organizing a room in so called "lobbies". So all rooms belong to lobbies. *PhotonNetwork.JoinOrCreateRoom* command is used to construct a room in the Photon network, which is then used to load the main scene. The system will first check if there is a registered room. If not, then the system will create a room. In order for all users to be visible in the main scene, the *PhotonNetwork.Instantiate* command is used to instantiate the avatar. In the current development, the application does not yet have the feature to create multiple rooms when there are two or more classes. So the user will automatically join the same room.

In Fig. 6 shows the results when the user joins the SVR lobby. At this time, the system will automatically generate an avatar. Meta Avatar SDK has 32 sample avatars that can be used. The avatar is selected based on the index number entered by the system. The application in this development does not provide customization of the avatar.

Fig. 6. Auto generate avatar and spawn in spawn point.

After users join the virtual room and enter main scene, users can interact with each other using voice chat and gestures by moving the Oculus controller (Fig. 7). From the test results, with the distance as shown in the picture, communication using voice chat sounds clear. Users can also move freely in the lobby using the Oculus controller's joystick. Users can also interact with particular objects, such as pick-up and dropping an object. In system testing, the user who acts as a lecturer explains the instructions and materials related to the quiz they would be doing.

Fig. 7. User interaction.

After receiving instructions for the quiz, the respondent took the quiz individually (Fig. 8). Through the trigger from the lecturer's avatar, the quiz UI will automatically appear around the respondent's avatar. In developing this SVR application, the quiz has no time limit, allowing respondents to take the quiz at their own pace.

Fig. 8. Participant taking quiz test.

The quiz system in this SVR is multiple choice, as shown in Fig. 9. In this test, the question bank is integrated directly into the system, so adding and changing questions must return to the developer side. Input received by the UI in confirming the answer through poke interaction to the provided answer buttons, labeled "A" and "B". This is done to make it easier for the user to press the answer through poke interaction. If the button is too small, the possibility of the user pressing the wrong button will be even greater. Therefore, information about answers in multiple choice is placed together on the quiz questions. In this test, 20 questions have been prepared that have been studied by the participants.

After the user completes the quiz, the quiz UI will display an indicating that the quiz is finished and provide a button for the user to close the UI. Furthermore, respondents will fill out a questionnaire to measure their satisfaction and interest in the developed application.

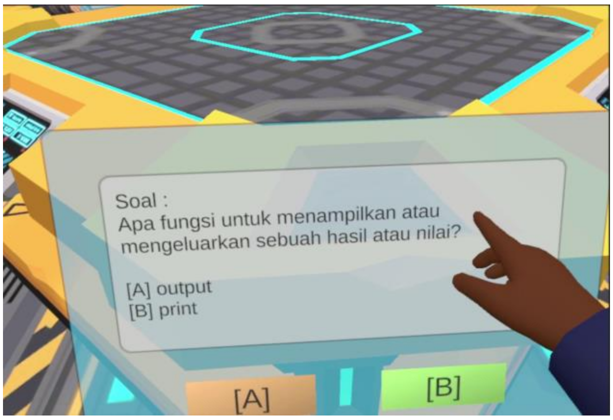

Fig. 9. First person view poke interaction on quiz UI.

B. *Performance Analysis*

The application's ability to render frames per second (fps) will be measured in this test. The application will be built as a standalone application and run on Oculus Quest 2 devices. Tests were performed at the default resolution setting (1832 × 1920) with a 72 Hz refresh rate. FPS recording is done within 5 minutes (300 seconds), and the average will be calculated. During this time, the player has been in the virtual room and interacted with other users, as well as taking quizzes through the UI that has been provided.

Fig. 10 shows the results of performance testing carried out within 300 seconds. From the results obtained, the average fps that the system can render is 76 fps. According to research [23, 24], a minimum of 60 fps is required to avoid motion sickness, with the ideal number being equal to the refresh rate or higher.

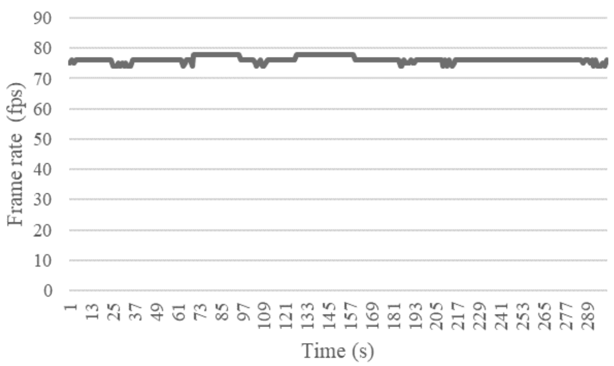

Fig. 10. Average frames per second.

The system's ability to render at 76 fps is achieved due to the compact scene and interaction models. The virtual room scene only has a total of 100,000 tris. Colliders are only applied to room objects and properties such as tables and others. And this scene doesn't have complex interactions, for example interactions and psychic simulations using rigid body on objects, such as throwing a cube or rolling a ball.

C. User Study

Experimental results from application development to measure the level of satisfaction and interest of the application to users. Data were collected through a questionnaire based on 6 variables in the PIECES framework: Performance, Information and Data, Economy, Control and Security, Efficiency, and Service. SVR application testing will be carried out by 14 students who are currently enrolled in the first-year basic programming course of the informatic engineering degree. Table I shows the number of questions on each variable from the PIECES framework.

TABLE I: DOMAIN PIECES FRAMEWORK

No.	Variable	Number of Questions
1	Performance	5
2	Information and Data	8
3	Economics	2
4	Control and Security	3
5	Efficiency	2
6	Service	4

The process of data analysis using the Importance Performance Analysis (IPA) method is obtained from the questionnaire using the Likert scale (Table II) [25], which aims to measure the level of satisfaction and interest of the respondents.

TABLE II: LIKERT SCALE OF SATISFACTION AND INTEREST

No.	Answer Options		Score
	Level of Satisfaction	Level of Interest	
1	Very Satisfied	Very Interest	5
2	Satisfied	Interest	4
3	Quite Satisfied	Quite Interest	3
4	Unsatisfied	Not Interest	2
5	Very Dissatisfied	Very Not Interest	1

Furthermore, to determine the average level of satisfaction using the following formula equation.

$$Avg = \frac{TSQ}{NQ} \tag{1}$$

where:

Avg: Average level of satisfaction/interest

TSQ: Total score of the Questionnaire

NQ: Number of Questionnaire

The calculation results will show the level of satisfaction and interest based on the range of values defined by Kaplan and Norton [26]. Value range and indicators as shown in Table III.

TABLE III: AVERAGE OF SATISFACTION AND INTEREST

Value Range	Satisfaction Predicate	Interest
1.00 – 1.79	Very Dissatisfied	Very Not Interest
1.80 – 2.59	Not Satisfied	Not Interest
2.60 – 3.39	Quite Satisfied	Quite Interest
3.40 – 4.79	Satisfied	Interest
4.80 – 5.00	Very Satisfied	Very Interest

The average number of satisfaction and interest from 14 respondents, calculated using the PIECES framework, is shown in Table IV.

TABLE IV: RESULT OF PIECES FRAMEWORK SATISFACTION AND INTEREST PREDICATE

	Satisfaction	Interest
Performance	4.06	4.06
Information and Data	4.11	4.28
Economics	4.17	4.22
Control and Security	4.17	4.22
Efficiency	4.06	4.17
Service	4.22	4.22

Based on the results of the data analysis and calculations, the average level of satisfaction and interest received a positive response. Respondents agree that the use of SVR technology can help the learning process. The learning process becomes more interactive and expressive with virtual spaces and avatars. Based on the data obtained through the PIECES Framework, the average value of interest is 4.19 and 4.13 for the average satisfaction value. This proves that the respondents are interested and satisfied with the SVR application as a learning medium.

V. DISCUSSION

The development of virtual applications in the field of education is quite advanced, using various tools depending on the specific needs of each case. For example, some SVR development using VRChat or RecRoom. However, this makes SVR applications dependent on the platform being used. In this study, SVR application development uses the Meta Avatar SDK, allowing it to be published and run as a standalone application. The downside of this system is the attachment to Meta accounts. Using a device that is automatically integrated with a Meta account such as the Oculus Quest will not be a problem. However, if the goal is to create a multi-platform application that other users can use, such as PCs, a special feature to log in to a Meta account may be required. Overall, the Meta Avatar SDK is a relatively easy-to-use package for developing SVR applications, as it includes 32 sample avatars and a simple interaction kit module.

This SVR application can also be developed by implementing web services for learning module management such as quizzes, allowing users to add learning materials more efficiently without returning the application to the developer side [27]. Not only quiz development, SVR also has basic interaction input that can be used to interact with certain objects. This feature can be used to develop more complex learning modules, such as assembling simple IoT equipment with a drag-and-drop system of objects into specific parts of the motherboard [28, 29]. By doing so, the SVR application can provide users a more interactive and expressive learning experience.

VI. Conclusion

This study presents the development of Social Virtual Reality (SVR) for learning media to support Merdeka Belajar. The developed SVR application is able to accommodate multi-users and allows them to interact through voice chat using Photon Pun 2. It also utilizes the Meta Avatar SDK, which provides 32 sample avatars with lip sync and hand gesture features. Based on the performance testing results, the application can render 76 frames per second at an average. Based on the questionnaire results using the PIECES Framework, the average value of interest is 4.19 and the average satisfaction value is 4.13, indicating that students are satisfied and interested in the SVR learning method.

SVR has the potential to support Merdeka Belajar effectively. SVR alters how people communicate, connect, and socialize via immersive and interactive 3D scene, voice communication and avatar with gesture and lip sync. Especially if it is equipped with a web service for learning module management, gamification and integration into the Moodle LMS.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

The conceptualization of the research was developed by Hestiasari Rante and Cahya Miranto. The formal analysis and design of methodology was done by Muhammad Agus Zainuddin and Felix Pasila. The implementation of the research and game development was carried out by Cahya Miranto and Evianita Dewi Fajrianti. Hestiasari Rante and William Irawan was in charge of supervision and validation. Review and editing was done by Hestiasari Rante, Cahya Miranto, Evianita Dewi Fajrianti. All authors contributed to the writing of the article, read and approved the final version of the manuscript.

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